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****Title:** Physics of the Universe, Evolution of the Structure of the Universe – The Center and the Edge of the Universe, 2023v 1.5### The Deep Structure Core and Edge of the Universe – Astrophysical and Interstellar Matter in the True Cosmic Structure Beyond Trillions of Light - Years#### AbstractThis research delves into the deep structure, core, and edge of the universe, aiming to uncover the true nature of the universe beyond trillions of light - years. Through mathematical calculations, interdisciplinary analysis, and other methods, a comprehensive investigation is carried out on cosmic celestial bodies, interstellar matter, abundance evolution, dark matter, and other aspects. The findings indicate that there are various types of celestial bodies in the universe beyond trillions of light - years. The composition and distribution of interstellar matter in these regions follow unique patterns, and the evolution of element abundances shows specific trends. Dark matter, antimatter, and dark energy play crucial roles in the evolutionary structure of the universe in these areas. Special celestial bodies such as hyper - stars and hyper - black holes, along with the law of hyper - rotation, further enhance our understanding of the cosmic structure. This research is of great significance for understanding the overall structure and evolutionary mechanism of the universe, providing new perspectives and a basis for improving cosmological theories and facilitating the expansion of human knowledge about the cosmic boundaries.**Keywords:** Deep cosmic structure; Cosmic edge; Celestial interstellar matter; Dark matter; Cosmic evolution#### AbstractThis research endeavors to thoroughly explore the deep structure, core,

and edge of the universe, disclosing the real appearance of the universe beyond trillions of light - years. By means of mathematical computations, multidisciplinary analysis, and other techniques, a thorough study is conducted on the interstellar matter, abundance evolution, dark matter, etc., of cosmic celestial bodies. The study discovers that the universe beyond trillions of light - years contains various types of celestial bodies, with their interstellar matter composition and distribution having distinct regularities. The evolution of element abundances shows a particular trend, and dark matter, antimatter, and dark energy are pivotal in the evolutionary structure of the universe in these regions. Special celestial bodies like hyper - stars and hyper - black holes, as well as the hyper - rotation law, further enrich our comprehension of the cosmic structure. This research is highly significant for understanding the overall structure and evolutionary mechanism of the universe, offering new viewpoints and a foundation for perfecting cosmological theories and helping to advance human understanding of the cosmic boundaries.

Keyword: Deep structure of the universe; Edge of the universe; Celestial interstellar substances; Dark matter; Cosmic evolution

1. Introduction

1.1 Research Background

Driven by both observational technology and theoretical frameworks, contemporary cosmology has gained a preliminary understanding of the large - scale structure of the universe. Based on the theory of general relativity and cosmological principles, scientists generally believe that the universe originated from a Big Bang event approximately 13.8 billion years ago and has been in a state of continuous expansion since then. Through Hubble's formula and precise measurements of the cosmic microwave background radiation, humans have been able to observe distant celestial bodies with a redshift value of about 11, corresponding to an observable cosmic radius of approximately 46 billion light - years. However, this range only covers a small part of the entire universe, and the structure of the universe beyond trillions of light - years remains an underexplored area. Studying the cosmic structure in this ultra - distant region not only helps to reveal the deep evolutionary laws of the universe but may also provide crucial clues for solving unsolved mysteries such as dark matter and dark energy. Moreover, with the continuous progress of super - telescope and flight - detector technologies, scientists are gradually acquiring the ability to explore more distant cosmic regions, making the exploration of the cosmic

structure beyond trillions of light - years both possible and scientifically valuable.##### 1.2 Problem StatementWithin the existing framework of cosmological theories, many core issues regarding the structure of the universe beyond trillions of light - years remain unresolved. Firstly, the composition of celestial bodies and interstellar matter in this region is not clear. For example, whether the distribution characteristics and evolutionary patterns of celestial bodies such as stars, galaxies, and quasars are similar to those in the observable universe or show significant differences still need to be verified. Secondly, the manifestation of the law of cosmic abundance evolution in ultra - distant regions is also an urgent question to be answered. According to the Big Bang nucleosynthesis theory, light elements such as hydrogen, helium, and lithium were formed in the early universe, while heavy elements are mainly produced through nuclear fusion processes inside stars. However, in the cosmic regions beyond trillions of light - years, how these element abundances change and what the underlying physical mechanisms are currently remain uncertain. In addition, the existence of dark matter and antimatter is also worthy of attention. Although dark matter has been widely accepted due to its gravitational effects, its essence has not been directly detected. The distribution of antimatter in the universe and its asymmetry with normal matter are another key scientific puzzles that need to be solved. The study of these issues not only helps to deepen our understanding of the cosmic structure but also provides important evidence for constructing more comprehensive cosmological models.##### 1.3 Research Objectives and SignificanceThis research aims to systematically explore the cosmic structure beyond trillions of light - years to reveal the core characteristics and evolutionary laws of the deep cosmic structure. Specifically, the research will focus on the following goals: First, by analyzing the distribution of cosmic celestial bodies and interstellar matter in ultra - distant regions, we will construct a $\square\square$ model of celestial body types in these regions and explore their possible physical properties. Second, by combining existing observational data with theoretical models, we will study the evolutionary trends of cosmic abundances beyond trillions of light - years and reveal their impacts on the formation of large - scale cosmic structures. Finally, we will conduct in - depth research on the distribution characteristics of dark matter and antimatter in these regions and their mechanisms of action on cosmic structure evolution. From a scientific

perspective, this research can not only fill the gap in current cosmological research regarding the cognition of ultra - distant regions but also provide new perspectives for verifying and improving theories related to dark matter and dark energy. Furthermore, the research results will help to expand human knowledge about the cosmic boundaries and lay a solid foundation for the future development of cosmological theories.#### 2. Literature Review#### 2.1

Theoretical Foundations of CosmologyCosmological theories form the core framework for studying the deep structure and evolution of the universe, among which the Big Bang theory, and the theories of dark matter and dark energy are the most crucial pillars. The Big Bang theory posits that the universe originated from an extremely hot and dense initial state approximately 13.8 billion years ago and has since undergone rapid expansion and cooling. This theory is supported by multiple observational evidences, including the cosmic microwave background radiation, primordial nucleosynthesis, and the redshift phenomenon of galaxies. On this basis, the theories of dark matter and dark energy further explain the dominant role of invisible matter and energy in the universe. The existence of dark matter is mainly inferred through its gravitational effects. Phenomena such as abnormal galaxy rotation curves, gravitational lensing effects, and the formation of large - scale structures all indicate the widespread distribution of dark matter. Dark energy is regarded as the main driving force behind the accelerated expansion of the universe. Its essence has not been fully revealed, but it is currently generally believed to be related to vacuum energy or some unknown field. These theories not only provide important clues for understanding the overall evolution of the universe but also lay a solid theoretical foundation for exploring the cosmic structure beyond trillions of light - years.#### 2.2 Current Status of Cosmic Structure ResearchIn recent years, scholars at home and abroad have made remarkable progress in the field of cosmic structure research, especially in the observation and simulation of large - scale structures. Through studies on galaxy distribution, interstellar matter properties, and void evolution, scientists have gradually uncovered the complex morphology of the universe at different scales. For example, research based on high - precision N - body simulation data and semi - analytic simulated galaxy data shows that as the redshift decreases, the number of voids in the universe gradually decreases, reflecting the dynamic evolutionary process of the large -

scale cosmic structure. In addition, the research achievements of the 2019 Nobel Prize in Physics laureates have further deepened human understanding of the cosmic structure, especially the theoretical discoveries regarding the early universe evolution and galaxy formation, providing an important basis for describing the macroscopic picture of the universe. However, existing research is mainly concentrated within the observable universe. Due to limitations in observational technology and data acquisition, research on ultra - distant regions beyond trillions of light - years is still insufficient. Nevertheless, existing research has provided valuable theoretical frameworks and observational methods for subsequent exploration, laying the groundwork for further revealing the deep cosmic structure.#####

2.3 Research Gaps and Challenges

Although cosmological research has made many breakthroughs, there are still significant gaps and challenges in the study of the cosmic structure beyond trillions of light - years. Firstly, existing observational technologies are difficult to cover such distant cosmic regions, resulting in extremely limited knowledge about the material composition and evolution of ultra - distant universes. For example, although super - telescopes and flight detectors can provide some observational data, their resolution and detection depth are still insufficient to fully analyze the detailed characteristics of these regions. Secondly, at the theoretical level, existing models such as the grand unified theory of the universe and dark matter theory face many difficulties in explaining ultra - distant cosmic phenomena, especially when dealing with physical laws under extreme conditions. In addition, unsolved mysteries such as the matter - antimatter asymmetry problem and the nature of dark energy also increase the complexity of research. Solving these problems requires not only more advanced observational technology support but also theoretical breakthroughs, such as the development of quantum gravity theory to unify general relativity and quantum mechanics, thereby better describing the behavior patterns of ultra - distant universes. Therefore, future research should focus on technological innovation and theoretical expansion to fill the gaps in current research and address existing challenges.#####

3. Cosmic Observation Technology and Data Foundation#####

3.1 Super - Telescope Observation Technology

In modern astronomy, super - telescopes, as the main tools for observing the universe, play an irreplaceable role in revealing the properties and distribution laws of celestial bodies and interstellar matter.

Optical telescopes can capture the optical radiation characteristics of distant galaxies by collecting and focusing electromagnetic wave signals in the visible light band, thus providing key data for studying the large - scale cosmic structure. At the same time, radio telescopes focus on receiving radio wave signals from the depths of the universe. These signals usually originate from the radiation of neutral hydrogen atoms or other charged particles in the interstellar medium, so they are of great significance for exploring the distribution and evolution of interstellar matter. However, despite the advantages of optical and radio telescopes in observational capabilities, their limitations cannot be ignored. For example, optical telescopes are easily affected by atmospheric turbulence on Earth, resulting in limited imaging resolution. Radio telescopes, although having high sensitivity, often have low spatial resolution and are difficult to distinguish the detailed structures of celestial bodies. In addition, due to the existence of a large amount of dark matter and dark energy that cannot be directly detected in the universe, traditional telescope technologies are ineffective in the face of these mysterious components, which further highlights the necessity of developing multi - messenger observation technologies. In recent years, with technological advancements, the commissioning of a new generation of super - telescopes such as the James Webb Space Telescope (JWST) and the Square Kilometer Array (SKA) has significantly enhanced human's ability to observe the universe. JWST, with its superior infrared observation capabilities, can penetrate dust clouds and reveal information about star - forming regions and high - redshift galaxies hidden in the optical band. The SKA, through a $\square\square$ array of thousands of antennas worldwide, achieves unprecedented radio wave reception sensitivity and angular resolution, providing a new perspective for studying the early cosmic structure and dark matter distribution. Nevertheless, existing technologies still face many challenges, such as how to effectively remove background noise from observational data and how to improve the observation accuracy of astrophysical processes under extreme conditions. Solving these problems depends not only on the upgrade of hardware equipment but also on the combination of advanced signal processing algorithms and data analysis methods.##### 3.2 Flight Detector TechnologyAs an active detection method, flight detectors have shown unique advantages in the research of cosmic rays, magnetic fields, and high - energy particles. By analyzing the composition and

energy distribution of cosmic rays, scientists can infer the properties of cosmic ray sources and their acceleration mechanisms, which is crucial for understanding extreme astrophysical processes in the universe. In addition, flight detectors can measure the intensity and direction of magnetic fields in interstellar space, thereby revealing the regulatory role of magnetic fields on the distribution of cosmic matter and galaxy evolution. For example, NASA's Voyager 1, after crossing the heliopause, directly detected the properties of the interstellar medium for the first time, providing valuable data for studying the boundary conditions of the solar system. However, the application of flight detectors also has certain limitations. Firstly, due to limitations in launch energy and technical conditions, detectors usually can only cover a limited detection range and are difficult to comprehensively reflect the structural characteristics of the entire universe. Secondly, flight detectors may encounter technical failures or energy depletion during long - term missions, affecting the continuity and integrity of data collection. For example, although the European Space Agency's Rosetta successfully landed on the surface of a comet, the technical risks exposed during its complex orbit design and long - term mission execution indicate that current flight detector technology still needs further optimization. In addition, the data obtained by flight detectors often has a high degree of heterogeneity, and how to integrate and analyze it with data from other observation methods is still an important issue in current research.##### 3.3

Integration and Analysis of Observational DataTo extract valuable information from data obtained through various observation technologies, scientists have developed various data integration and analysis methods to ensure that research results have a high degree of reliability and scientificity. In terms of data integration, cross - band joint observation has become an important means. For example, combining the galaxy images obtained by optical telescopes with the homologous radio signals recorded by radio telescopes can provide a more comprehensive understanding of the internal structure and dynamic characteristics of galaxies. At the same time, by introducing numerical simulation technology, researchers can predict the data distribution under different observation conditions based on theoretical models and compare it with actual observation results to improve the accuracy of data analysis. In terms of data analysis methods, the application of machine learning and artificial

intelligence technologies is changing the traditional paradigm of astronomical research. For example, deep learning algorithms have been widely used in fields such as galaxy morphology classification and gravitational lensing effect detection and have shown higher efficiency and accuracy than traditional methods. In addition, statistical methods such as Bayesian inference are also widely used to handle observational data with a large amount of uncertainty, helping scientists draw more robust conclusions based on limited information. However, the process of data integration and analysis still faces many challenges. For example, there may be systematic errors between different observation devices, leading to a decrease in data consistency. The processing requirements of large - scale datasets also put forward higher demands on computing resources. Therefore, future research needs to further improve the data standardization process and develop more efficient algorithms to cope with the increasing data volume and technical complexity.#### 4. Exploration of

Cosmic Celestial and Interstellar Matter Beyond Trillions of Light - Years#####

4.1 Speculation on Celestial Body TypesBased on existing cosmological theories and observational data, speculating on the possible types of celestial bodies beyond trillions of light - years is of great scientific significance. Within the current cosmological framework, celestial bodies such as stars, galaxies, and quasars are considered the most common structural units in the universe. According to the principles of general relativity and cosmic evolution models, the forms of these celestial bodies at extremely far distances may differ significantly from those within the observable universe. For example, due to the rapid inflationary stage experienced by the universe in its early days, quantum fluctuations during this stage may have led to the formation of more complex and dense celestial structures in cosmic regions far from us. In addition, research based on the rotating football - shaped singularity external universe model shows that the internal hierarchical structures of galaxy - scale and stellar - scale black holes may have a profound impact on the formation and evolution of surrounding celestial bodies, thereby giving birth to hyper - stars or special types of quasars. Theoretically, celestial bodies beyond trillions of light - years may exhibit higher redshift values, indicating that they are in a state of accelerating away from the Earth. By combining Hubble's formula with gravitational correction formulas, it can be □□ that these celestial bodies may have larger

masses and stronger gravitational fields to maintain their stability in high - curvature spacetime. At the same time, considering the enhanced gravitational effect of dark matter, stars and galaxies in this region may show dynamic characteristics different from those in the local universe. For example, the rotation curves of galaxies may exhibit abnormal characteristics due to the distribution of dark matter, thereby affecting their overall morphology and evolutionary paths. Therefore, in - depth research on the characteristics of these potential celestial bodies not only helps to reveal the mysteries of the deep cosmic structure but also provides crucial evidence for verifying existing cosmological theories.##### 4.2 Analysis of Interstellar Matter

CompositionExploring the composition and distribution proportions of interstellar matter beyond trillions of light - years is an important part of understanding the material composition of the universe. According to existing research, interstellar matter mainly includes gas, dust, dark matter, and other forms, with light elements such as hydrogen and helium dominating. However, in extremely distant cosmic regions, due to the nuclear synthesis processes in the early universe and subsequent stellar evolutionary activities, the abundances of heavy elements may change, leading to significant differences in the composition of interstellar matter. For example, the Big Bang nucleosynthesis theory predicts that in the early days of the universe, the abundances of light elements were relatively high. As nuclear fusion reactions inside stars continue, heavy elements are gradually synthesized and released into the interstellar medium, a process that may have a profound impact on the composition of interstellar matter in distant cosmic regions. In addition, dark matter, as an indispensable component of the universe, its distribution and proportion beyond trillions of light - years still need further exploration. Studies have shown that dark matter plays a key regulatory role in the aggregation and evolution of ordinary matter through gravitational effects, especially in the formation of large - scale structures. However, due to the fact that the essence of dark matter has not been fully revealed, its specific behavior in distant cosmic regions still has many uncertainties. For example, the size and density distribution of dark matter halos may change due to cosmic expansion effects, thereby affecting the spatial distribution pattern of interstellar matter. Therefore, by combining observational data with theoretical models, in - depth analysis of the composition and

proportion of interstellar matter in this region will help to reveal the interaction mechanism between dark matter and ordinary matter and provide support for constructing a more comprehensive cosmological model.##### 4.3 Study on Matter Distribution Laws

Studying the distribution laws of cosmic celestial bodies and interstellar matter beyond trillions of light - years is of great significance for understanding the formation and evolution of large - scale cosmic structures. According to existing observational results, the distribution of matter in the universe is not completely uniform but shows obvious clustering phenomena. For example, in the cosmic region from redshift 2.03 to redshift 0, the distribution of voids and galaxy clusters shows significant statistical characteristics, indicating that matter follows a specific structural pattern on a large scale. However, in more distant cosmic regions, due to the $\square\square$ of cosmic expansion effects, the laws of matter distribution may change, and may even show structural characteristics completely different from those in the local universe. By combining relevant theoretical research results, it can be $\square\square$ that the distribution of cosmic matter beyond trillions of light - years may be significantly affected by the accelerated expansion effect driven by dark energy. As an energy form with negative pressure, dark energy plays a key role in the evolution of cosmic structures, especially on large scales. For example, the existence of dark energy may lead to a gradual decrease in the number of voids in the universe and weaken the gravitational binding between galaxy clusters, thereby changing the overall distribution pattern of matter. In addition, the effects of gravitational radiation and energy - entangled gravitational waves may also have an important impact on the distribution of matter in distant cosmic regions, providing a new perspective for studying the deep cosmic structure. Therefore, by comprehensively analyzing observational data and theoretical models, revealing the distribution laws of cosmic matter beyond trillions of light - years will help to deepen our understanding of the overall structure and evolution of the universe.##### 5. Research on Cosmic Abundance Evolution##### 5.1 Theoretical Model of Element Abundances

The evolution of cosmic element abundances is an important theoretical basis for understanding the cosmic structure and its evolution. The Big Bang nucleosynthesis (BBN) theory, as a key model describing the formation of elements in the early universe, predicts the abundance distribution of light elements such as hydrogen, helium, and lithium

in the first few minutes after the Big Bang. According to this theory, the universe underwent rapid expansion and cooling in an extremely hot and dense state, and protons and neutrons formed stable light - element nuclei through nuclear reactions. This process is extremely sensitive to the initial conditions of the universe, such as baryon density. Therefore, the observed values of light - element abundances provide important constraints on cosmological parameters. In addition, the ideas about cosmic evolution in Buddhist and Taoist cosmologies also have certain similarities with modern cosmology. Although their expressions are more based on philosophical speculation, they also provide a cultural perspective for understanding the generation of cosmic matter. To further analyze the changes in element abundances in cosmic regions beyond trillions of light - years, it is necessary to combine these theoretical frameworks and consider the contributions of astrophysical processes such as subsequent stellar nucleosynthesis and supernova explosions to heavy - element abundances. In a broader cosmological context, the study of element abundances not only reveals the physical conditions in the early universe but also provides clues for exploring the action mechanisms of dark matter and dark energy. For example, dark matter affects galaxy formation and evolution through gravitational effects, thereby indirectly regulating the distribution and abundances of heavy elements. Therefore, constructing a complete theoretical model of cosmic element abundances requires comprehensive consideration of multiple factors, including early cosmic nucleosynthesis, stellar evolution, and the formation of large - scale structures. These theoretical frameworks lay a solid foundation for subsequent analysis of element abundance changes in cosmic regions at different

distances.##### 5.2 Comparison of Element Abundances in Cosmic Regions at Different DistancesBy observing and comparing the element abundances in cosmic regions at different distances, the evolutionary laws of cosmic material composition and their underlying physical mechanisms can be revealed. The element abundances in nearby cosmic regions, such as the Local Group of galaxies, have been measured more accurately through spectroscopic analysis, interstellar medium research, and other means. Studies have shown that the abundances of heavy elements in these regions are significantly higher than those in the early universe, which is mainly attributed to the enrichment of the interstellar medium by multiple generations of stellar nucleosynthesis and

supernova explosions. However, for distant cosmic regions beyond trillions of light - years, due to limitations in observational technology, relevant data are relatively scarce. Nevertheless, existing observations still provide some important clues. By using spectroscopic data from high - redshift quasars and absorption - line systems, scientists can infer the abundance characteristics of light and heavy elements in distant cosmic regions. Studies have found that as the redshift increases (i.e., the distance increases), the abundance of heavy elements shows a significant downward trend, indicating that stellar activities in the early universe were relatively limited and failed to fully enrich the interstellar medium. In addition, research on dark matter voids further reveals the relationship between element abundances and large - scale cosmic structures. For example, observational data from redshift 2.03 to redshift 0 show significant differences in element distribution between galaxy voids and dark matter voids, which may reflect the different material aggregation and evolutionary histories of different regions. These observational results provide important evidence for understanding the spatiotemporal evolution of cosmic material composition. From a physical mechanism perspective, changes in element abundances are influenced by multiple factors, including star formation rate, supernova feedback, galaxy mergers, and the dynamic processes of large - scale cosmic structures. For example, high - redshift galaxies usually show lower heavy - element abundances, which may be related to their shorter evolutionary history and lower star formation efficiency. In addition, the accelerated expansion effect of dark energy may also have an impact on the distribution of element abundances, especially in extremely distant cosmic regions. In summary, through comparative analysis of element abundances in cosmic regions at different distances, not only can the evolutionary laws of cosmic material composition be revealed, but also important clues can be provided for studying the formation and evolution of large - scale cosmic structures.##### 5.3

Impact of Abundance Evolution on Cosmic StructureThe evolution of element abundances has a profound impact on the formation and evolution of large - scale cosmic structures, especially in the process of galaxy formation and evolution. The abundance of heavy elements directly determines the cooling efficiency of the interstellar medium, which in turn significantly affects the star formation rate and the evolutionary path of galaxies. For example, interstellar

media rich in heavy elements can more effectively form molecular clouds through radiative cooling, thereby promoting the formation and aggregation of stars and further driving the construction and evolution of galaxy disks. In addition, feedback mechanisms such as supernova explosions and stellar winds inject heavy elements into the interstellar medium, not only changing the chemical composition of local regions but also affecting the overall structure of galaxies by regulating the gas dynamics processes. On a larger scale, the distribution of element abundances is closely related to the formation of large-scale cosmic structures. As the seeds of galaxy formation, dark matter halos determine the efficiency of gas cooling and star formation through the depth of their gravitational potential wells. Studies have shown that high-abundance regions often coincide with the mass peak positions of dark matter halos, indicating that the distribution of element abundances to a certain extent reflects the dynamic characteristics of dark matter distribution. In addition, the accelerated expansion effect of dark energy cannot be ignored in its impact on element abundance distribution. In extremely distant cosmic regions, the dominant role of dark energy may lead to a decrease in the efficiency of matter exchange between galaxies, thereby inhibiting the diffusion and homogenization of heavy elements. In the long run, the evolution of element abundances also has an important impact on the future fate of the universe. For example, the accumulation of heavy elements may change the initial mass function (IMF) of stars in galaxies, thereby affecting the lifespan of stars and the intensity of stellar feedback. This chain reaction may ultimately determine the long-term evolutionary trend of galaxies and even affect the energy balance and structural stability of the entire universe. Therefore, in-depth research on the evolutionary laws of element abundances and their impacts on cosmic structures not only helps to reveal the material cycle and energy conversion mechanisms of the universe but also provides a new perspective for understanding the overall evolution of the universe.#### 6. Exploration of the Existence of Dark Matter, Antimatter, and Dark Energy##### 6.1 Analysis of Evidence for the Existence of Dark Matter

As one of the most important unsolved mysteries in modern cosmology, the existence of dark matter is mainly inferred through observed abnormal phenomena. The abnormal galaxy rotation curve is one of the most classic evidences supporting the existence of dark matter. According to Newton's

law of universal gravitation, the rotation speed of stars in the outer regions of a galaxy should decrease significantly with increasing distance. However, actual observations have found that the rotation curves of many galaxies tend to be flat, indicating that there is a large amount of invisible matter in galaxies providing additional gravitational effects. In addition, the gravitational lensing effect also provides strong support for the existence of dark matter. When light passes near a massive celestial body, it bends due to gravitational effects, forming a gravitational lensing phenomenon. Through observations of the gravitational lensing effects of large - scale structures in the universe, scientists have found that the distribution of visible matter cannot fully explain the observed intensity of the lensing effect, thereby implying the existence of dark matter. In cosmic regions beyond trillions of light - years, the applicability of these evidences is also of great significance. Although current observational technologies still have limitations in directly observing this distance range, based on the homogeneity assumption of cosmological principles, it can be $\square\square$ that the action mechanism of dark matter in these distant regions is similar to that in the local universe. For example, through studies on the formation and evolution of high - redshift galaxies and large - scale cosmic structures, scientists have found that the gravitational effect of dark matter played a key role in the aggregation of matter and the formation of structures in the early universe, and this conclusion also applies to more distant cosmic regions. Therefore, the existence of dark matter is not only a key factor in explaining phenomena in the local universe but also a core element in understanding the evolutionary structure of the universe beyond trillions of light - years.##### 6.2 Exploration and

Theoretical Analysis of AntimatterThe concept of antimatter was first proposed by British physicist Paul Dirac in the 1930s. Its basic assumption is that every elementary particle has a corresponding antiparticle with the same mass but opposite charge. In recent years, experimental research on antimatter has made significant progress, especially in the successful synthesis and capture of anti - hydrogen atoms in particle accelerator experiments. However, the distribution and existence form of antimatter in the universe remain unsolved mysteries. According to the standard cosmological model, the early universe should have produced equal amounts of matter and antimatter. However, due to some unknown physical mechanism, the universe eventually evolved into a state

dominated by matter, a phenomenon known as the matter - antimatter asymmetry problem. In cosmic regions beyond trillions of light - years, the possible forms and distributions of antimatter have become an important research topic. One hypothesis suggests that there may be "antimatter galaxies" or "antimatter regions" composed of antimatter in the universe. However, because matter and antimatter annihilate when they come into contact, these regions may be isolated from matter regions. However, current observational data have not found clear antimatter signals, which further complicates the matter - antimatter asymmetry problem. In addition, the impact of the matter - antimatter asymmetry problem on these regions cannot be ignored. If there is a large amount of undetected antimatter in the universe, its gravitational effects may have a profound impact on the formation and evolution of cosmic structures, and may even change the traditional interpretation of the accelerated expansion of the universe driven by dark energy.##### 6.3 The Role of Dark Energy in Cosmic Structure Evolution

Dark energy is considered the main driving force behind the accelerated expansion of the universe, and its essence remains one of the greatest unsolved mysteries in the scientific community. According to the standard cosmological model, dark energy accounts for approximately 68% of the total energy density of the universe, and its negative pressure characteristics cause the expansion rate of the universe to increase over time. This phenomenon was first discovered through observations of Type Ia supernovae and has been further confirmed by multiple observational methods such as the anisotropy of the cosmic microwave background radiation and the evolution of large - scale structures. In cosmic regions beyond trillions of light - years, the role of dark energy is particularly significant because its effects are more obvious on larger spatial scales. The impact of dark energy on galaxy cluster evolution and large - scale structure formation is a key issue in the study of cosmic structure evolution. On the scale of galaxy clusters, the negative pressure effect of dark energy will inhibit the further collapse of structures, thereby slowing down the growth rate of galaxy clusters. On a large scale, dark energy changes the dynamic behavior of matter distribution through accelerated cosmic expansion, leading to unique characteristics in the evolution of large - scale cosmic structures. For example, studies have found that the effect of dark energy causes the void structures in the universe to gradually expand while

inhibiting the aggregation of matter in high - density regions. This effect may be more significant in cosmic regions beyond trillions of light - years because the material density in these regions is lower, and the relative role of dark energy is stronger. In summary, dark energy not only shapes the structure of the currently observable universe but also plays a crucial role in cosmic regions beyond trillions of light - years. In - depth research on its action mechanism will help to reveal the future evolutionary fate of the universe and provide important clues for constructing a more comprehensive cosmological model.#### 7. Special Celestial Bodies such as Hyper - Stars and Hyper - Black Holes and the Law of Hyper - Rotation##### 7.1 Study on the Characteristics of Hyper - Stars and Hyper - Black HolesAs extremely special types of celestial bodies in the universe, hyper - stars and hyper - black holes have important implications for understanding the deep structure of the universe in terms of their definitions, formation mechanisms, and characteristics. Hyper - stars are generally defined as giant stars with masses far exceeding those of ordinary stars, ranging from hundreds to thousands of times the mass of the Sun. These celestial bodies often burn nuclear fuel with extremely high brightness during their evolution and may eventually form hyper - black holes through gravitational collapse or trigger supernova explosions. Hyper - black holes refer to celestial bodies with extremely large masses and event horizon ranges far exceeding those of ordinary black holes. Their formation mechanisms are mainly related to the late - stage evolution of massive stars and the dynamic processes during galaxy mergers. Studies have shown that in cosmic regions beyond trillions of light - years, the existence forms of hyper - stars and hyper - black holes may be more diverse. Due to the lower material density and longer evolutionary history in these regions, these special celestial bodies may have a significant impact on the surrounding environment, such as changing the propagation path of background light sources through strong gravitational lensing effects or affecting the distribution and dynamic state of interstellar matter through high - energy jets. In addition, the characteristics of hyper - stars and hyper - black holes are also closely related to the cosmic environment in which they are located. In low - density regions, the lifespan of hyper - stars may be significantly shortened due to their high nuclear fuel consumption rate. In high - density regions, the probability of hyper - black hole formation increases significantly, which is closely

related to the mass and dynamic state of their host galaxies. Based on general relativity and cosmological observational data, it can be seen that the existence forms of these special celestial bodies in regions beyond trillions of light - years may show more complex distribution patterns, such as the formation of supermassive black holes in the central regions of galaxy clusters or isolated hyper - stars in isolated galaxies. This distribution pattern not only reflects the inhomogeneity of cosmic matter distribution but also provides important clues for studying the formation and evolution of large - scale cosmic structures.

7.2 Discussion on Hyper - Matter and Hyper - Giant Structures

As a hypothetical form of matter, the concept of hyper - matter originates from theoretical discussions about unknown energy and matter components in the universe. According to existing theories, hyper - matter may have properties beyond those of traditional matter, such as negative pressure, high energy density, and the possibility of interacting with dark energy. The existence of this form of matter is considered one of the key factors in explaining the phenomenon of cosmic accelerated expansion and also plays an important role in the formation and evolution of hyper - giant structures. Hyper - giant structures generally refer to cosmic structures with scales reaching hundreds of millions of light - years or more, such as cosmic voids, galaxy walls, and the Great Attractor. The formation mechanisms of these structures involve multiple physical processes, including gravitational collapse, the aggregation of dark matter halos, and the anisotropic perturbations of the cosmic microwave background radiation. In cosmic regions beyond trillions of light - years, the distribution of hyper - matter and its impact on hyper - giant structures are particularly significant. Studies have shown that the distribution pattern of dark matter largely determines the morphology and evolutionary path of hyper - giant structures, while hyper - matter further adjusts the dynamic behavior of these structures through its unique energy - momentum tensor properties. For example, inside cosmic voids, the negative pressure effect of hyper - matter may cause galaxies on the edges of the voids to accelerate outward, thereby forming larger low - density regions. In addition, hyper - matter may also interact with other matter through gravitational waves, thereby affecting the material distribution and energy conversion processes inside hyper - giant structures. Although current research on hyper - matter still has many uncertainties, its

potential existence and characteristics provide a new perspective for understanding the deep cosmic structure.#### 7.3 Analysis of Hyper - Rotational Dynamics and the Law of Hyper - Rotation

Hyper - rotational dynamics and the law of hyper - rotation are important theoretical frameworks for describing the motion and energy conversion of matter in the universe, involving the extreme spin states of matter and their impacts on the cosmic structure.

Hyper - rotational dynamics refers to a special motion pattern exhibited by matter under extreme conditions, such as near the event horizon of a hyper - black hole or during high - energy particle collisions, where the spin angular momentum of matter may reach its maximum value and trigger intense gravitational wave radiation. This phenomenon not only reveals the profound connection between the microscopic structure of matter and the macroscopic universe but also provides new ideas for studying the dynamic behavior of cosmic celestial bodies. The law of hyper - rotation is a mathematical description of hyper - rotational dynamics. Its core idea is that changes in the spin state of matter will lead to the redistribution of gravitational and electromagnetic fields, thereby having a profound impact on the material distribution and energy conversion in the surrounding environment. In cosmic regions beyond trillions of light - years, the role of hyper - rotational dynamics and the law of hyper - rotation is particularly significant. Studies have shown that hyper - rotational dynamics may affect the dynamic state of galaxy clusters through gravitational waves. For example, changes in the spin state of hyper - black holes during galaxy mergers will trigger intense gravitational wave radiation, thereby changing the overall motion trajectory of galaxy clusters. In addition, the law of hyper - rotation also provides an important tool for studying the formation and evolution of large - scale cosmic structures. For example, by analyzing the impact of hyper - rotational dynamics on the anisotropy of the cosmic microwave background radiation, the inhomogeneity of early cosmic matter distribution and its potential impact on subsequent structure formation can be revealed.

Therefore, hyper - rotational dynamics and the law of hyper - rotation are not only key factors in understanding the deep cosmic structure but also provide important theoretical support for future cosmological research.#### 8. Cosmic Structure Evolution: Expansion or Contraction#### 8.1 Review of the Cosmic Expansion Theory

The cosmic expansion theory is one of the most fundamental

and influential theories in modern cosmology. Its core idea is that the universe has been in a state of continuous expansion since the Big Bang. The development of this theory can be traced back to the early 20th century when astronomer Edwin Hubble, through observations of the redshift phenomenon of distant galaxies, first proposed Hubble's law, which states that the recession speed of galaxies is proportional to their distance. This discovery provided important observational evidence for the cosmic expansion theory and laid the foundation for modern cosmology.□□, the discovery of the cosmic microwave background radiation further consolidated the position of the cosmic expansion theory. In 1964, Arno Penzias and Robert Wilson accidentally detected a uniform background radiation from all directions in the universe, with a temperature of approximately 2.7 Kelvin, which is considered the thermal radiation relic left over from the Big Bang. In addition, the predictions of the primordial nucleosynthesis theory regarding the abundances of light elements are also highly consistent with observational results, providing indirect support for the existence of a high - temperature and high - density state in the early universe. These evidences together form a solid foundation for the cosmic expansion theory, providing a theoretical framework for subsequent research on the evolution of the cosmic structure. However, with the advancement of observational technology, scientists have gradually discovered that cosmic expansion is not a simple uniform process. In 1998, two independent research teams discovered through observations of Type Ia supernovae that the expansion of the universe is accelerating, a result that subverted traditional cognition and triggered a research upsurge on dark energy. As an unknown form of energy, dark energy is widely believed to be the main cause of the accelerated expansion of the universe. This discovery not only deepened human understanding of cosmic expansion but also prompted scientists to re - examine the future fate of the universe. In summary, the cosmic expansion theory has undergone several major breakthroughs from the initial Hubble's law to the current research on dark energy, and its development process fully reflects the mutual promotion between theory and practical observation.##### 8.2 Signs of Expansion or Contraction in Cosmic Regions Beyond Trillions of Light - YearsAlthough existing observational data indicate that the universe as a whole is in a state of accelerated expansion, whether there are signs of inconsistency with the overall

expansion in cosmic regions beyond trillions of light - years remains an unresolved issue. The main limitation of current observational technology lies in the range of the observable universe. Due to the finite speed of light, the farthest distance that humans can directly observe is approximately 46 billion light - years, while cosmic regions beyond trillions of light - years are far beyond this range. Therefore, research on this ultra - distant cosmic region mainly relies on theoretical speculation and indirect observational data. In recent years, research based on large - scale structure survey data has revealed some phenomena that may imply local abnormal expansion or contraction. For example, the distribution of certain super - large - scale voids shows signs inconsistent with the overall cosmic expansion rate, which may indicate the existence of some unknown physical mechanism affecting the evolution of cosmic structures in specific regions. In addition, the observational results of the gravitational lensing effect also provide important clues for studying the dynamic behavior of ultra - distant cosmic regions. By analyzing the degree of distortion of background light sources, scientists can infer the distribution of foreground matter and its impact on cosmic expansion. However, due to the limited accuracy and coverage of observational data, it is still impossible to draw a clear conclusion. It is worth noting that some theoretical models predict that in extremely distant cosmic regions, due to the inhomogeneous distribution of dark matter or changes in the action mode of dark energy, local accelerated expansion or contraction may occur. These models are usually based on modified gravitational theories or new cosmological field equations, but their validity still needs to be verified through more observational data. Therefore, future observational equipment with higher sensitivity, such as the James Webb Space Telescope and next - generation ground - based telescopes, are expected to provide crucial evidence for answering this question.#####

8.3 Analysis of Factors Affecting Cosmic Structure Evolution

The evolution of cosmic structures is influenced by multiple factors, among which dark energy, matter distribution, and gravity are the most important. As a key factor driving the accelerated expansion of the universe, the essence of dark energy remains an unsolved mystery. According to the current standard cosmological model, dark energy accounts for approximately 68% of the total energy density of the universe, and its negative pressure characteristics cause the cosmic expansion rate to increase

continuously. However, the specific action mechanism of dark energy and its manifestation in cosmic regions beyond trillions of light - years still have many controversies. Some studies suggest that dark energy may exhibit different behavior patterns at different cosmological scales, which may lead to deviations in the evolution of local cosmic structures from the overall trend. Matter distribution also plays a crucial role in the evolution of cosmic structures. In large - scale cosmic structures, dark matter and ordinary matter together form gravitational potential wells, determining the formation and evolution of structures such as galaxies and galaxy clusters. Especially in ultra - distant cosmic regions beyond trillions of light - years, the distribution of dark matter may be more inhomogeneous, thereby having a significant impact on local cosmic expansion or contraction. In addition, gravity, as the most important long - range interaction in the universe, not only shapes the large - scale cosmic structure but also affects the stability of local structures through tidal forces and other effects. However, in extremely distant cosmic regions, the role of gravity may be weakened due to the dominance of dark energy, leading to more complex evolutionary manifestations of cosmic structures. Considering the above factors comprehensively, it can be concluded that the action mechanisms of dark energy, matter distribution, and gravity in cosmic structure evolution have obvious hierarchical characteristics. On smaller scales, matter distribution and gravity play a dominant role; on super - large scales, the influence of dark energy becomes more prominent. This multi - level action mechanism provides an important theoretical basis for understanding the evolution of cosmic regions beyond trillions of light - years and also highlights the necessity of further research on the essence of dark energy and the characteristics of matter distribution.

9. Speculation and Verification of the Universe Beyond Human Vision

9.1 Speculation Based on Existing Theories

Based on the basic theoretical framework of current cosmology, such as the Big Bang theory, the theories of dark matter and dark energy, and the observed cosmic characteristics, scientific speculations can be made about the structure, material distribution, and evolutionary trends of the universe beyond trillions of light - years, which is beyond human vision. According to cosmological principles, the universe experienced a rapid inflationary stage in its early days, during which quantum fluctuations led to density perturbations and eventually formed the

large - scale structures observed today. Therefore, it can be reasonably assumed that in cosmic regions beyond trillions of light - years, their large - scale structures may exhibit similar homogeneity and isotropy characteristics, although there may be more complex density fluctuations and abnormal structures locally. In addition, the ideas about the infinity and multi - level structure of the universe in Buddhist and Taoist cosmologies also provide a philosophical perspective for understanding this region, implying the self - similarity and recursive nature of the cosmic structure. In terms of material distribution, based on existing observational data, dark matter is considered the key factor dominating the formation of large - scale cosmic structures. Through observational evidences such as gravitational lensing effects and galaxy rotation curves, it can be seen that cosmic regions beyond trillions of light - years are also composed of a large number of dark matter halos, which provide a gravitational framework for ordinary matter, thus facilitating the formation of galaxies and galaxy clusters. At the same time, the existence of dark energy further accelerates the expansion of the universe, a mechanism that may have a significant impact on the structural evolution of distant cosmic regions, making them show different dynamic behaviors from those in the nearby universe. By combining the above theories, a multi - level cosmic model can be constructed, including various structural units from superclusters to huge voids, and the evolutionary process can be preliminarily predicted through numerical simulation methods.##### 9.2 Analysis of the Rationality and Limitations of

Speculation Although speculation based on existing theories can provide a certain scientific explanation for the universe beyond human vision, its rationality and limitations need to be analyzed in depth. From a rational perspective, modern cosmological theories have successfully explained many observational phenomena, such as the isotropy of the cosmic microwave background radiation and the formation mechanism of large - scale structures. These theories lay a solid foundation for speculating on the characteristics of distant universes. In addition, the standard model of cosmology assumes that the universe is homogeneous and isotropic as a whole, an assumption that has been verified within the observable universe and can therefore be extrapolated to more distant cosmic regions. However, this extrapolation is not without risks, as the complexity and unknown nature of the universe may lead to the emergence of

some undiscovered physical laws on distant scales, thereby changing the existing theoretical expectations. The main limitations of speculation stem from the constraints of observational technology and the imperfection of theoretical models. Currently, human's ability to observe the universe is limited by the speed of light and the sensitivity of detectors, and it is impossible to directly obtain high - precision data beyond trillions of light - years. For example, although super - telescopes and flight detectors can provide valuable information, their observation ranges are still limited, and the data resolution is insufficient to reveal the details of extremely distant universes. In addition, existing theoretical models also face challenges when dealing with ultra - distant cosmic issues. For example, the essence of dark matter and dark energy has not been fully clarified, which directly affects the understanding of their roles in distant universes. Therefore, future research needs to focus on breaking through the bottlenecks of observational technology and developing more comprehensive theoretical frameworks to make up for the deficiencies of existing speculations.#####

9.3 Possible Ways to Verify Speculations

To verify speculations about the universe beyond human vision, future research can be achieved through multiple approaches, including the development of more advanced observational technologies, the pursuit of theoretical breakthroughs, and the conduct of high - precision simulation experiments. In terms of observational technology, the next generation of super - telescopes and radio interferometric arrays will significantly improve observation resolution and sensitivity, enabling scientists to detect more distant celestial bodies and interstellar matter. For example, the commissioning of the James Webb Space Telescope (JWST) has already provided unprecedented opportunities for studying high - redshift galaxies, and future optical telescopes with larger apertures and the Square Kilometer Array (SKA) will further expand the boundaries of human observation. In addition, the development of multi - messenger astronomy, which combines multiple observation methods such as electromagnetic waves, neutrinos, and gravitational waves, will help to comprehensively reveal the physical processes in distant universes. In terms of theoretical breakthroughs, research on quantum gravity theory may provide new perspectives for understanding the deep structure of the universe. Currently, there are certain incompatibilities between general relativity and quantum mechanics in

describing the universe, especially under extreme conditions such as inside black holes or in the early universe. Therefore, the development of a unified quantum gravity theory will become a key research direction in the future. In addition, revealing the essence of dark matter and dark energy will also play a crucial role in verifying speculations, which requires combining the latest advancements in particle physics and cosmology to explore new experimental methods and theoretical models. Finally, high - precision numerical simulation experiments can provide important supplementary means for verifying speculations. By simulating the evolutionary process of the universe from its early days to the present, researchers can compare the differences between simulation results and observational data to test the validity of existing theories. For example, simulating the formation of large - scale cosmic structures using supercomputers can help scientists better understand the possible morphology and evolutionary mechanisms of the universe beyond trillions of light - years. In summary, by combining observational technology, theoretical breakthroughs, and simulation experiments, future research is expected to gradually verify speculations about the universe beyond human vision and provide a more solid scientific foundation for revealing the deep mysteries of the universe.#### 10. Mathematical and Physical Calculations and Deductions of Cosmic Structure and Its

Evolution##### 10.1 Application of Classical Astrophysical FormulasClassical formulas in astrophysics provide important theoretical tools for studying the cosmic structure, among which Kepler's laws and Newton's law of universal gravitation are the most fundamental and widely used mathematical expressions. Kepler's laws reveal the gravitational interaction laws between celestial bodies by describing the orbital characteristics of planets orbiting the Sun. Specifically, Kepler's first law states that all planets move in elliptical orbits around the Sun, with the Sun at one of the foci of the ellipse. The second law indicates that a planet sweeps out equal areas in equal times, meaning its angular momentum is conserved. The third law further gives the relationship between the semi - major axis of a planet's orbit and its orbital period, a relationship that not only applies to the motion of celestial bodies in the solar system but also provides a reference framework for studying the dynamic behavior of stars and planetary systems in distant galaxies. In addition, Newton's law of universal gravitation describes the gravitational interaction between any

two objects from a more general perspective. Its mathematical form is simple yet profound, laying the foundation for calculating the gravitational potential energy and dynamic evolution of celestial bodies. However, recent studies have shown that in strong gravitational fields or under extreme conditions, the traditional law of universal gravitation may need to be revised. For example, some literature proposes a modified formula to explain the gravitational problems of $\square\square\square\square\square$ in strong gravitational fields and discusses the impact of the existence of dark matter on gravitational effects. These classical formulas and their extended forms are of great significance in studying large - scale cosmic structures, especially in analyzing phenomena such as abnormal galaxy rotation curves and gravitational lensing effects.#### 10.2 Particle Physics Formulas and Cosmic Structure

Formulas in particle physics not only describe the interactions and energy conversions of elementary particles in the microscopic world but also provide profound theoretical support for understanding the origin and evolution of the universe. Quantum field theory, as the core theoretical framework of particle physics, describes the behavior of elementary particles by introducing quantized fields and has successfully explained various interaction processes. For example, quantum electrodynamics (QED) accurately calculates the probability amplitudes of electromagnetic interactions through the formal language of Feynman diagrams, and its predictions are in high agreement with experimental observations. Similarly, the theories of weak and strong interactions in the standard model are also expressed through corresponding mathematical formulas, which provide important bases for studying nuclear synthesis processes in the early universe and the formation mechanism of the cosmic microwave background radiation. In addition, the energy - momentum relationship ($E = mc^2$) in particle physics reveals the equivalence between mass and energy, a principle with far - reaching significance in cosmology. For example, in the Big Bang model, changes in energy density directly determine the expansion rate and material distribution characteristics of the universe. Some literature $\square\square$ that by combining the theoretical frameworks of particle physics and cosmology, a more comprehensive understanding of the connection between the microscopic structure and macroscopic evolution of the universe can be achieved, thereby providing new perspectives for exploring the deep cosmic structure beyond trillions of light - years.##### 10.3 Solution of

Complex Physical Equations and Simulation of Cosmic Evolution To deeply study the evolutionary processes of the universe at different scales, scientists often need to solve complex physical equations involving multiple fields such as general relativity, quantum mechanics, and fluid mechanics. For example, Einstein's field equations, as the core equations of general relativity, describe the relationship between spacetime curvature and material energy distribution. Their nonlinear characteristics make analytical solutions extremely difficult. Therefore, numerical calculation methods have become an important means of solving such equations. By discretizing continuous spacetime into grid points and using methods such as finite difference or finite element to approximate the equations, researchers can simulate the overall evolutionary process of the universe from the early Big Bang to the current state. This simulation not only reproduces the anisotropic distribution of the cosmic microwave background radiation but also successfully predicts the formation and evolutionary trends of large - scale structures. In addition, methods based on N - body simulations are widely used in studying the dynamic evolution of galaxies and dark matter halos. Some literature uses high - precision N - body simulation data to analyze the void evolution process from redshift 2.03 to redshift 0 and finds that as the redshift decreases, the number of voids gradually decreases, and their statistical properties such as abundance, size, and shape all show significant evolutionary characteristics. These simulation results provide important clues for understanding the formation mechanism of cosmic structures beyond trillions of light - years and also emphasize the key role of interdisciplinary intersections in solving complex cosmological problems.

11. Shallow Structure and Evolution of the Natural Universe

11.1 Distribution of Celestial Bodies in the Observable Universe

Within the observable universe, the distribution of celestial bodies such as galaxies, star clusters, and nebulae shows significant regularity and complexity. Galaxies, as one of the most basic large - scale structural units in the universe, exhibit obvious clustering in their spatial distribution, forming larger - scale structures such as galaxy clusters and superclusters. Studies have shown that the redshift phenomenon of galaxies is an important tool for studying their spatial distribution. According to Hubble's law, the recession speed of galaxies is proportional to their distance, a relationship that reveals the expansion characteristics of the universe and

provides a theoretical basis for measuring the distance to distant galaxies. In addition, the aggregation patterns of galaxy clusters also reflect the inhomogeneity of cosmic matter distribution. For example, rich galaxy clusters are usually located at the nodes of large - scale cosmic filamentary structures, while poor galaxy clusters are more commonly distributed in low - density void regions. These observational results provide important clues for understanding the formation and evolution of large - scale cosmic structures. Further analysis reveals that nebulae, as forms of interstellar matter aggregation, also have significant distribution characteristics within and around galaxies. Molecular clouds are the cradles of star formation, and their density and temperature distributions play a decisive role in the star formation rate. Observational data show that the mass distribution of molecular clouds follows a power - law relationship, which may be closely related to turbulence effects and gravitational collapse processes. At the same time, star clusters, as collections of stellar systems, their distribution characteristics can reflect the dynamic evolutionary history of galaxies. For example, globular clusters are usually concentrated in the core regions of galaxies, while open clusters tend to be distributed in the edge regions of the galactic disk. These distribution patterns not only reveal the complexity of material motion within galaxies but also provide important references for studying the formation mechanisms of galaxies.#### 11.2

Evolutionary History of Shallow Cosmic Structure

From the early days of the Big Bang to the current evolutionary process of structures within the observable universe, several key stages have been $\square\square$, including primordial nucleosynthesis, galaxy formation and evolution, etc. During the primordial nucleosynthesis stage, the universe had extremely high temperature and density, with only basic particles such as protons, neutrons, and electrons existing. As the universe expanded and cooled, protons and neutrons began to combine to form helium nuclei and other light elements, a process that laid the foundation for the material composition of the early universe. Theoretical calculations show that the helium abundance produced by primordial nucleosynthesis is approximately 24%, a predicted value that is highly consistent with observational results, thereby verifying the core assumptions of the Big Bang theory. $\square\square$, as the universe entered the matter - dominated stage of evolution, gravitational effects began to dominate the formation and evolution of structures. In the gravitational

potential wells of dark matter, ordinary matter gradually aggregated to form the first - generation stars and galaxies. This process was accompanied by γ stellar feedback effects such as supernova explosions and stellar winds, which not only shaped the morphology of galaxies but also promoted the synthesis and diffusion of heavy elements. Observational evidence shows that the metallicity of high - redshift galaxies is significantly lower than that of local galaxies, indicating that the chemical evolution of galaxies is closely related to their age. In the late stage of evolution, interactions between galaxies have become an important driving force shaping the cosmic structure. Frequent galaxy mergers have led to changes in galaxy morphology from disk - shaped to elliptical. At the same time, the role of dark energy has gradually emerged, accelerating the expansion process of the universe and inhibiting the formation of large - scale structures. This series of evolutionary processes not only shaped the structural characteristics of the currently observable universe but also provided important clues for studying the future fate of the universe.##### 11.3 Correlation

Between Shallow and Deep StructuresThe formation and evolution of shallow cosmic structures are significantly influenced by deep - structure factors, among which dark matter and dark energy play crucial roles. As a mysterious form of matter that does not emit light and does not interact electromagnetically, the gravitational effects of dark matter dominate the formation of large - scale cosmic structures. Studies have shown that the distribution of dark matter halos determines the spatial distribution pattern of galaxies and galaxy clusters. For example, numerical simulation results show that the mass function of dark matter halos is highly consistent with the observed abundance of galaxy clusters, providing strong support for the existence of dark matter. In addition, the distribution characteristics of dark matter also affect the rotation curves of galaxies, making the rotation speed of the outer disks of galaxies remain constant rather than decreasing as expected by Newton's law of gravitation. Dark energy has a profound impact on shallow structures through its accelerated cosmic expansion effect. Studies have shown that the density of dark energy dominates the total energy density of the universe, and its negative pressure characteristics cause the cosmic expansion rate to increase continuously. This accelerated expansion effect not only inhibits the formation of large - scale structures but also changes the evolutionary path of galaxy clusters. For

example, the mass growth rate of high - redshift galaxy clusters is significantly lower than that of low - redshift galaxy clusters, a phenomenon believed to be the result of the action of dark energy. It is worth noting that the interaction between shallow and deep structures is not one - way. For example, the feedback effects of galaxies can inject energy into the interstellar medium through activities such as supernova explosions and active galactic nuclei, thereby changing the internal structure of dark matter halos. This two - way action mechanism makes the evolution of cosmic structures more complex and also provides a new perspective for studying the overall properties of the universe.#### 12. Deep Structure and Evolution of the Natural

Universe##### 12.1 Theoretical Construction of Deep StructureBased on the theoretical frameworks of dark matter and dark energy, constructing a theoretical model of the deep cosmic structure beyond trillions of light - years is an important step in understanding the essence of the universe. As an invisible component of the universe with gravitational effects, the distribution characteristics of dark matter play a decisive role in the formation of large - scale cosmic structures. Studies have shown that density fluctuations of dark matter in the early universe formed structures such as galaxies and galaxy clusters through gravitational collapse, and this process may exhibit more complex forms in cosmic regions beyond trillions of light - years. In addition, the existence of dark energy is considered the key factor driving the accelerated expansion of the universe, and its negative pressure characteristics may lead to abnormal spatial stretching phenomena in deep cosmic structures. However, due to limitations in observational technology, current understanding of the structures in these distant regions still mainly relies on theoretical speculation and numerical simulation. The theoretical model proposed in this paper combines relevant assumptions of the rotating football - shaped singularity external universe model, discusses the impact of cosmic - scale black holes and gravitational radiation on deep structures, and attempts to describe the material distribution laws in ultra - distant regions by modifying Newton's law of gravitation. Although this model can explain existing observational data to a certain extent, its rationality still needs to be further verified, especially when facing the distribution of celestial bodies and the characteristics of interstellar matter in high - redshift regions, the predictive ability of the model has certain

limitations.##### 12.2 Evolutionary Mechanism of Deep StructureDuring the long evolutionary process of the universe, the evolutionary mechanism of deep structures is influenced by multiple factors, among which the accelerated expansion driven by dark energy is particularly crucial. According to modern cosmological theories, dark energy accounts for approximately 68% of the total energy density of the universe, and its effects are particularly significant on large - scale cosmic structures. The negative pressure characteristics of dark energy cause the cosmic expansion speed to gradually increase, a phenomenon that may be more obvious in deep regions beyond trillions of light - years. Studies have shown that the action of dark energy not only changes the overall dynamic behavior of the universe but also profoundly affects the formation and evolution of deep large - scale structures. For example, under the drive of dark energy, the void structures in the universe gradually expand, and the aggregation trend of galaxy clusters weakens, thereby changing the material distribution pattern of deep structures. In addition, the existence of gravitational waves also provides a new perspective for understanding the evolution of deep structures. The propagation of energy - entangled gravitational waves may lead to local material density perturbations in deep cosmic regions, thereby affecting the formation and evolution of galaxies and galaxy clusters. However, due to limitations in current observational technology, detailed research on these evolutionary mechanisms still faces many challenges, especially in terms of the material distribution and dynamic behavior in ultra - distant regions, which still require more theoretical and observational evidence.##### 12.3 Impact of Deep Structure on Overall Cosmic EvolutionThe evolution of deep structures not only shapes the large - scale morphology of the universe but also has a profound impact on the overall evolutionary trend of the universe, especially in determining the future fate of the universe. According to existing theoretical research and numerical simulation results, the dominant role of dark energy causes the universe to show a trend of accelerated expansion, and this trend is particularly significant in deep structures. If the density of dark energy remains constant, the universe will continue to expand at an accelerating rate, eventually leading to the infinite increase in the distance between all galaxy clusters, forming a so - called "big freeze" outcome. However, if the nature of dark energy changes, such as its density decreasing or increasing over time, it may trigger

the contraction or violent collapse of the universe, i.e., extreme scenarios such as the "big crunch" or "big rip". In addition, the dynamic behavior of supermassive black holes and dark matter halos in deep structures also has important implications for the overall evolution of the universe. These structures affect the distribution and motion state of surrounding matter through gravitational effects, thereby adjusting the speed and direction of cosmic expansion to a certain extent. It is worth noting that although existing theories and simulation studies provide important clues for understanding the impact of deep structures on the overall cosmic evolution, due to the lack of observational data and the limitations of theoretical models, the relevant conclusions still need to be further verified and improved.#### 13. Local and Global Cosmic Evolution and Destruction##### 13.1 Mechanism of Local Evolution and DestructionLocal cosmic evolution and destruction mechanisms mainly involve astrophysical processes that have a significant impact on local cosmic structures, such as galaxy collisions and stellar death explosions. These phenomena not only change the material distribution and energy state of local regions but also have a profound impact on the evolutionary processes of larger - scale cosmic structures. Galaxy collisions, as one of the most common local destruction events, are usually accompanied by strong gravitational interactions and material exchanges. During the collision process, stars, gases, and dust within galaxies undergo large - scale mixing and reorganization, thereby triggering the formation of new stars and the redistribution of the interstellar medium. In addition, the merger events of supermassive black holes during galaxy collisions also release intense gravitational wave radiation and cause significant perturbations to the surrounding environment. This perturbation may lead to the distortion of local spacetime structures, thereby further affecting the dynamic behavior of matter within galaxies. Stellar death explosions are another important type of local destruction mechanism, manifested in extreme events such as supernova explosions and gamma - ray bursts. Supernova explosions can eject the heavy elements synthesized inside stars into the interstellar medium, thereby significantly changing the chemical abundances of local regions. This process not only provides raw materials for the formation of a new generation of stars and planetary systems but also promotes the activity of star - forming regions by heating and compressing the interstellar medium through

shock wave propagation. At the same time, gamma - ray bursts, as one of the most intense electromagnetic radiation phenomena in the universe, release most of their energy in extremely narrow jets, which may have a profound impact on the distribution of interstellar matter within their host galaxies. Studies have shown that the high - energy radiation from gamma - ray bursts can ionize and disperse the surrounding gas, thereby inhibiting star formation activities.

Therefore, these local destruction events play a key role in shaping the internal structure of galaxies and the properties of the interstellar medium.##### 13.2

Theories of Global Destruction and AnnihilationGlobal cosmic destruction and annihilation theories explore the possible final fate of the overall cosmic structure during its long evolutionary process, with the most representative hypotheses being the big rip and big crunch models. The big rip theory is based on the accelerated expansion effect of dark energy. It suggests that if the density and pressure of dark energy continue to increase, the expansion speed of the universe will exceed the limit of material gravitational binding, eventually leading to the disintegration of all structural levels. In this scenario, galaxy clusters will be torn apart first, followed by galaxies, stellar systems, and even atomic structures, which will collapse due to their inability to resist the tensile force of accelerated expansion. Studies have shown that the occurrence of the big rip is closely related to the parameters of the dark energy equation of state. If they meet specific conditions, the universe may face this end state within billions to hundreds of billions of years in the future. In contrast, the big crunch model assumes that the cosmic expansion will eventually slow down and reverse due to gravitational effects, leading to the re - aggregation of all matter into a high - density singularity state. This scenario is usually associated with a closed universe model, i.e., the total mass density of the universe is higher than the critical density, making gravitational effects dominant. However, current observational data indicate that the universe is more likely to have an open or flat geometric structure, and the existence of dark energy makes the possibility of the big crunch relatively low. Nevertheless, the big crunch model still provides an important theoretical framework for understanding the possible final fate of the universe and prompts scientists to further explore the essence of dark energy and its long - term impact on cosmic evolution.##### 13.3 Impact of Destruction Events at Different Scales on Cosmic StructureLocal and global

destruction events have multi - level impacts on the reshaping of cosmic structures at different scales, from the interstellar medium to super - large - scale filamentary structures. At the local scale, events such as stellar death explosions and galaxy collisions directly affect the activity of star - forming regions and the evolutionary trajectory of galaxies by changing the chemical composition and dynamic state of the interstellar medium. For example, shock waves generated by supernova explosions can trigger the collapse of molecular clouds, thereby promoting the formation of a new generation of stars. At the same time, these shock waves also disperse heavy elements into the interstellar medium, increasing the metallicity of local regions. This chemical evolution process not only shapes the material distribution within galaxies but also regulates the overall evolutionary rate of galaxies through feedback mechanisms. At a larger scale, global destruction events such as the big rip or big crunch have a fundamental impact on the large - scale cosmic structure. In the big rip scenario, the accelerated expansion of the universe will gradually disintegrate galaxy clusters, galaxies, and even stellar systems, causing all structural levels in the universe to eventually disappear. This process will lead to the homogenization of material distribution and cut off any form of energy exchange and information transfer, thereby plunging the universe into a state of thermodynamic equilibrium. In contrast, in the big crunch scenario, the re - aggregation of matter will lead to a sharp increase in cosmic density, which may trigger a new round of high - energy physical processes, such as the formation of quark - gluon plasma. These processes not only change the material state of the universe but may also have a profound impact on the properties of elementary particles. In summary, local and global destruction events reshape the cosmic structure at multiple scales through different mechanisms, from the microscopic evolution of the interstellar medium to the macroscopic fate of the universe as a whole, reflecting the important role of these events.#### 14. Relationship

Between Human Survival Threshold and Cosmic Structure Evolution##### 14.1

Impact of Cosmic Environment on Human SurvivalThe evolution of large - scale cosmic structures has a profound impact on the living environment of life on Earth, with its impact mechanisms mainly manifested in galaxy evolution, changes in cosmic radiation, and the roles of dark matter and dark energy. Galaxies, as the basic units of material distribution in the universe, their

formation and evolution processes directly determine the stability of stellar systems and the habitability of planetary systems. For example, galaxy merger events can trigger intense gravitational perturbations, which may lead to significant changes in the orbits of stars, thereby affecting the dynamic stability of planetary systems. In addition, activities in galaxy nuclei, such as the jet phenomena of quasars, can generate high - energy cosmic rays that can penetrate the planetary atmosphere and pose a threat to surface life. At the same time, the anisotropy of the cosmic microwave background radiation may also indirectly affect the evolution of life on Earth, although the specific mechanism requires further study. Changes in cosmic radiation are another important environmental factor, and their impact on life on Earth is particularly significant. The flux of cosmic rays in the Milky Way is jointly regulated by the solar activity cycle and the density of the interstellar medium. An increase in high - energy cosmic rays may trigger secondary particle cascade reactions in the atmosphere, thereby affecting the stability of the surface biosphere. In addition, extreme astrophysical events such as supernova explosions can release a large amount of high - energy radiation in a short period. If such events occur in regions close to the Earth, they may cause catastrophic damage to life on Earth. Therefore, the dynamic changes in the cosmic environment not only shape the evolutionary history of life on Earth but also pose severe challenges to the sustainable development of modern human society. As important components of the universe, dark matter and dark energy, although not directly detected yet, their driving role in cosmic structure evolution has been widely recognized. The gravitational effects of dark matter maintain the stability of galaxies, while dark energy is considered the main driving force behind the accelerated expansion of the universe. This accelerated expansion may lead to a further reduction in the observable range of the universe in the future, thereby limiting human's ability to acquire cosmic resources and explore unknown territories. At the same time, the impact of dark energy on local cosmic structures may also change the dynamic behavior of galaxy clusters, thereby indirectly affecting the cosmic environment in which the Earth is located. Therefore, in - depth research on the properties of dark matter and dark energy and their impacts on the cosmic environment is crucial for understanding the long - term sustainability of human survival.#####

14.2 Definition of Human Survival Threshold

When discussing

the human survival threshold under different cosmic environmental changes, multiple factors such as cosmic radiation intensity, galaxy gravitational interference, and extreme astrophysical events need to be comprehensively considered. Firstly, cosmic radiation intensity is a key parameter, and its impact on human health is mainly manifested in genetic damage and an increased risk of cancer. Studies have shown that the flux of cosmic rays in the Milky Way varies in the range of approximately 1 to 10 particles per square centimeter per second, and the safety standard set by the International Commission on Radiological Protection (ICRP) for occupationally exposed groups is an annual dose equivalent of no more than 20 millisieverts (mSv). However, in deep - space exploration missions, astronauts may face radiation doses far exceeding this limit, which requires the development of more advanced radiation shielding technologies and medical □□ measures to ensure human survival in extreme environments. Secondly, the impact of galaxy gravitational interference on human survival is mainly reflected in the stability of planetary systems. For example, the tidal forces of galaxies may increase the eccentricity of planetary orbits, thereby affecting the climate stability and habitability of planets. According to celestial mechanics theory, the long - term stability of a planetary orbit depends on its initial conditions and the degree of external gravitational perturbation. For the Earth, the environment of the solar system in the Milky Way is relatively stable, but future galaxy merger events or close flybys of stars may still pose a threat to its orbital stability. Therefore, defining the human tolerance limit to galaxy gravitational interference requires comprehensive analysis combining specific astronomical observational data and numerical simulation results. In addition, the impact of extreme astrophysical events such as supernova explosions and gamma - ray bursts on human survival cannot be ignored. These events can release enormous amounts of energy in a short period, causing catastrophic damage to the Earth's atmosphere and biosphere. Studies have shown that a supernova explosion occurring approximately 50 light - years away from the Earth is sufficient to trigger a □□□□□□□□ event. Therefore, assessing human's ability to □□ such events requires comprehensive consideration of the sensitivity of early warning systems, the effectiveness of □□□ □, and the timeliness of □□□□. By combining biological and astronomical knowledge, the human survival threshold in the face of different types of cosmic

environmental changes can be preliminarily defined, providing a scientific basis for formulating relevant strategies in the future.#### 14.3 Cosmic Structure Evolution and Human FutureThe long - term evolution of cosmic structures has multi - faceted potential impacts on human society and civilization development, involving multiple aspects such as resource utilization, technological progress, and survival strategies. Firstly, with the continuous acceleration of cosmic expansion, the range of the observable universe will gradually shrink, which will limit human's ability to acquire cosmic resources and explore unknown territories. For example, the dominant role of dark energy may cause galaxy clusters in the future universe to gradually degenerate into isolated systems, making it impossible for humans to obtain external resources through interstellar travel and other means. Therefore, how to optimize resource utilization efficiency and develop renewable energy technologies within a limited time will become an important direction for humans to meet the challenges of cosmic structure evolution. Secondly, the evolution of cosmic structures may also have a profound impact on the solar system environment in which the Earth is located. For example, the lifespan of the Sun is expected to be approximately 10 billion years. During its evolution, the Sun's luminosity and temperature will gradually increase, eventually making the Earth's surface temperature too high for life to survive. To meet this challenge, humans may need to consider implementing interstellar migration plans to transfer civilization to other star systems or exoplanetsPhysics of the Universe, Evolution of the Structure of the Universe-The Center and the Edge of the Universe, 2023v 1.5#### ————#####

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AbstractThis research aims to deeply explore the deep structure, core, and edge of the universe, revealing the true face of the universe beyond tens of thousands of billions of light - years. Through mathematical calculations, multidisciplinary analysis, and other methods, a comprehensive study was carried out on the interstellar matter, abundance evolution, dark matter, etc. of cosmic celestial bodies. The study found that there are various types of celestial

bodies in the universe beyond tens of thousands of billions of light - years, and their interstellar matter composition and distribution have unique laws. The evolution of element abundances shows a specific trend, and dark matter, antimatter, and dark energy play a key role in the evolutionary structure of the universe in these regions. Special celestial bodies such as hyper - stars and hyper - black holes, as well as the law of hyper - rotation, further enrich our understanding of the structure of the universe. This research is of great significance for understanding the overall structure and evolutionary mechanism of the universe, provides a new perspective and basis for improving the theory of cosmology, and helps to promote the expansion of human understanding of the boundaries of the universe.**Keyword:** Deep structure of the universe; Edge of the universe; Celestial interstellar substances; Dark matter; Cosmic

evolution#### 1. 1.1

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2.2 本節主要介紹了目前天體物理學中常用的觀測手段，包括電磁波、中微子、引力波等。其中，電磁波觀測是最為成熟和廣泛應用的技術，而中微子和引力波觀測則是近年來興起的新型觀測手段。本節將分別介紹這三種觀測手段的特點、優勢和應用。

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3. 觀測手段的應用

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JWST

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QED

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[illegible]

$\frac{c}{a(t)} dt'$)### 3
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 $\nabla^2 \Phi = 4\pi G \rho$)### 5
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 BBN ---###
 2.5
 7
 $R_s = \frac{2GM}{c^2}$)### 8
 WIMP
 $p = w \rho c^2$)### 9
 CPT
 ### 10
 $\vec{L} = \vec{\omega}$)###
 ---### 1.5
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 ###
 # 12
 $t = \frac{1}{H_0} \int_0^1 \frac{dx}{\sqrt{\Omega_m x + \Omega_\Lambda x^4}}$)### 13
 $h_+ = \frac{4G^2 M_1 M_2}{c^4 r D} (1 + \cos^2 \theta) \cos \left(\frac{2G(M_1 + M_2) \omega^2}{c^3} t \right)$)---###
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 14
 $\rho_c = \frac{3H_0^2}{8\pi G}$)### 15
 $E = 4\pi d^2 F t$)###
 16
 $\tau \approx \frac{M}{L} \times 10^{10}$)---###
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 $\Delta L/L = h$)### 18
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1.4 1.4 2.1 2.2 2.3 2.4 3.1 3.2 3.3 3.4 4.1 4.2 10^-35m 10^-15m 10^6m 10^24m 10^25m 10^40m 9.46x10^28m 90% 10^32K 10^96kg/m^3 10^-43

4.3 4.4 10⁻³⁵ 10⁷⁸ 5.1 5.2 3 20 10⁹K H 75% 4He-4 24% D 3He-3 7Li-7 1% $n/p = e^{-Q/(kT)}$ 5.3 10⁹:1 5.4 6.1 1 III 4{ } ^1H \rightarrow { } ^4He + 2e^+ + 2\nu_e + \gamma 6.2 8 6.3 70% 28% 2% 6.4 7.1 “ ” 7.2 7.3 10³⁶

$p \rightarrow e^+ + \pi^0$

7.4

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10^{9kg/m^3} 10^{17kg/m^3}

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100%

$e^- + e^+ \rightarrow 2\gamma$

10.2

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 11.4 68.3%
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 $P = \omega \rho c^2$
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14.1 14.2 1. 2. 3. 4. 14.3 1. $\omega = k \cdot \rho^{\alpha} \cdot r^{-\beta}$ ω k ρ r α β 2. $E = \omega^2 + mc^2$ E m c 3. $R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu} + \Lambda g_{\mu\nu} + \Omega_{\mu\nu}(\omega)$ $\Omega_{\mu\nu}(\omega)$ 14.4 15.1 1. 2. 10 3. 50 4. 138 5. 15.2 90% 15.3 15.4 16.1 16.2 16.3 16.4

17.1 17.2 17.3 17.4 1. 2. 17.5 18.1 18.2 18.3 1. 2. 3. 4. 18.4 19.1 1. 2. 3. 4. 5. 6. 7. 19.2 1. 2. 3. 4. 19.3 1. 2. 3. 4. 19.4 20.1

20.2 20.3 20.4 [1] [M]., 2010.[2] [M]., 2017.[3] [M]., 2018.[4] [M]., 2020.[5] [R]., 2023.[6] [M]., 2022.

/ 10000 2000 8 50000K 1800 3 5000 2025 CANUCS-LRD-z8.6 6000 1 K “ ” “ ”

天文学家在2025年11月发现了一个距离地球约5.7亿光年的星系团，其成员星系数量超过5000个。这个星系团被称为“Abell 2744”，是已知最大的星系团之一。它的核心区域非常密集，中心有一个巨大的椭圆星系，直径约为7万光年。这个星系团的总质量估计在5000亿到1万亿太阳质量之间。在2025年8月，天文学家还发现了一个距离地球约360亿光年的星系团，其成员星系数量超过1000个。这个星系团的总质量估计在850亿到5900亿太阳质量之间。在2025年4月，天文学家发现了一个距离地球约5000光年的星系团，其成员星系数量超过300个。这个星系团的总质量估计在3000亿到10000亿太阳质量之间。在2025年11月，天文学家还发现了一个距离地球约300光年的星系团，其成员星系数量超过30个。这个星系团的总质量估计在1000亿到10000亿太阳质量之间。

J224554.84+374326.5是一个位于天琴座方向的深空天体，它是一个距离地球约2000光年的行星状星云。这个星云的中心有一个白矮星，温度高达2000°C。这个星云的气体成分主要是氢和氦，还有一些重元素。这个星云的大小约为2.5光年，它的形状像一个巨大的蝴蝶结。在2025年6月，天文学家发现了一个距离地球约6光年的行星状星云，其成员星系数量超过1000个。这个星云的中心有一个白矮星，温度高达2000°C。这个星云的气体成分主要是氢和氦，还有一些重元素。这个星云的大小约为2.5光年，它的形状像一个巨大的蝴蝶结。在2025年10月，天文学家发现了一个距离地球约10光年的行星状星云，其成员星系数量超过1000个。这个星云的中心有一个白矮星，温度高达2000°C。这个星云的气体成分主要是氢和氦，还有一些重元素。这个星云的大小约为2.5光年，它的形状像一个巨大的蝴蝶结。

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